ALBEDO (750 nm) - COLOR (950/750 nm) DIAGRAM FOR THE MOON, ASTEROIDS AND METEORITES: MODELING OPTICAL MATURATION OF THE COSMIC BODY SURFACES.

L.F.Golubeva and D.I.Shestopalov, Shemakha Astrophysical Observatory, Shemakha, Azerbaijan 373243 (shestopalov_d@mail.ru).

Space weathering process changes albedo and color of planetary surface material and thus disguises optical properties of the unweathered equivalents [1]. Recently albedo *A*(750 nm) - color index *C*(950/750 nm) plots have been already utilized for modeling optical maturation of the lunar samples and the asteroid Eros surface [2,3,4,5]. In this work we construct general diagram for the lunar nearside, S-asteroids, and meteorites to calculate optical maturation trends.

Diagram construction. At first, it is necessary to find the links between albedo scale of the Moon, and scales of the asteroid geometric albedo and meteorite albedo measured in the laboratory. To resolve the task we attracted data of polarimetric measurements. For the Moon the correlation between visual albedo A_v of lunar areas in accordance with Lunar Photometric Map and their polarimetric slope *h* in accordance with observations by Dollfus was obtained in [6]. The correlation between visual polarimetric albedo p_v and *h* of asteroids is also known [7]. At last, the correlation between visual albedo B_v of meteorite samples measured by spectrophotometer with the integrating sphere and *h* was obtained in [8]. Taking into account that albedo - color diagram for the lunar nearside was already obtained [9], it makes sense to link the lunar albedo scale with asteroid and meteorite albedo scales. Having excluded polarimetric slope *h* from the above relationships we obtained: $A_v = (1.00\pm0.37)p_v^{(0.99\pm0.09)}$ and $A_v = (1.1\pm0.3)B_v^{(1.1\pm0.1)}$. Finally, albedo at λ = 750 nm in lunar albedo scale (that is *A*(750 nm)) for asteroids and meteorites is calculated with help color-index *C*(750/560 nm) that is known from reflectance spectra of these objects.

Data sets. S-asteroids with known polarimetric albedo [7] and spectra [10,11,12] and also spectra of the achondrites and ordinary chondrites measured with help of the integrating sphere [13] are used. We selected only meteorite spectra of the samples without terrestrial weathering (i.e. without any patina or rust).

Errors of the point coordinates on the albedo - color diagram (Fig.1) are caused both measurement precision and errors of the calculations by using albedo scale equations. These combined errors for asteroids and meteorites lie in the range 0.05 - 0.1 in units of albedo and in the range 0.02 - 0.08 in units of color index. As it is noted above, for the lunar nearside we use albedo-color diagram obtained in [9].

Theory. We assume that submicroscopic grains of the reduced iron (SMFe), product of the space weathering, are inclusions in the upper layer of the host material particles. Let c_1 be SMFe volume concentration in layer having thickness *t*. In that case optical density of the weathered particle $\tau_w = \alpha_h l + \beta_{Fe} b$, where α_h - absorption coefficient of the host particle, β_{Fe} - specific absorption coefficient of the SMFe inclusions, *l* - average optical pathlength in particle, and $b = 2c_1 t$. Using optical constants for metallic iron from [14] and Hapke theory [1] one can calculate β_{Fe}. Albedo of the powdered surface was calculated by geometrical-optics model [15] that establishes simple link between τ and *A*.

Giving *A*(750 nm) and *C*(950/750 nm) as starting conditions and varying *l* and c_1 one can calculate maturation trends, some of them are shown in Fig.1.

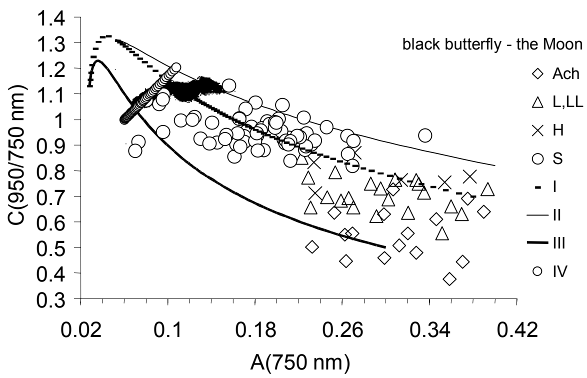

Fig.1. Albedo-color diagram for the Moon, S-asteroids and meteorites. Maturation tracks arise because of increasing SMFe concentration in the particles without changing their sizes (II) and with decreasing particle sizes (I, III, IV).

Discussion. The Moon, asteroids and meteorites occupy slightly recovering domains on *A*(750 nm) - *C*(950/750 nm) plot and present materials with different degree of the space weathering. Meteorites are samples of the unweathered mineral assemblies widespread on planetary surfaces, lunar surface - example of the material with high degree of the weathering, and most of asteroids have intermediate degree of surface weathering. One can calculate large number of maturation trends that show alteration of the optical parameters depending on the supposed properties of the body surfaces. In Fig.1 we give some of them which are very probable according to the present conception of weathering process. Initial *A* and *C* values were chosen in meteorite domain as far as particle sizes of meteorite samples are approximately equal. Hence, the optical parameters can vary due to Fe^2 content differences, in particular.

Trend I starting in the meteorite domain passes through central zone of the S-asteroid domain and approximates central cluster of the lunar domain (trunk of the "lunar butterfly"). The track describes the following: the decrease of particle sizes l of the initial (unweathered) material is accompanied with the increase of SMFe concentration c_1 in the particles.

Trend II is upper boundary of the domains occupied by the cosmic objects and approximates right wing of the lunar butterfly. For this track c_1 increases whereas $l \approx const.$

Trend III is the bottom boundary of the domains and simulates the same situation that trend I.

We couldn't find the transformation way for optical parameters A and C of the meteorite domain to approximate the left wing of the lunar butterfly. Therefore we assumed there exist dark unweathered material with "neutral" spectrum. In that case decreasing particle sizes and increasing SMFe concentration in particles can generate the trend IV.

Variations of the model parameters for maturation trends are shown in the table.

Condition	l(μm)	c_1	$b=2c_1 t$
	Trend I		
Start	70	0	0
Ast.domain,beginning	67,6	0,0241	0,0048
End of domain	61,4	0,0861	0,0172
Moon domain,beginning	60	0,1001	0,0200
End of domain	57	0,1301	0,0260
	Trend II		
Start	70	0	0
Ast. domain,beginning	70,2	0,0121	0,00242
End of domain	71,4	0,0701	0,0140
Moon domain,beginning	71,6	0,0841	0,0168
End of domain	72,4	0,1201	0,0240
	Trend III		
Start	70	0	0
Ast. domain,beginning	62,8	0,0721	0,0144
End of domain	54	0,1601	0,0320
Moon domain,beginning	49	0,2101	0,0420
	Trend IV		
Start	100	0	0
Moon domain,beginning	59,5	0,0441	0,0088
End of domain	31,9	0,0741	0,0148

So, if shortly, we show that optical parameters of the primordial unweathered material can move owing to space weathering in ranges known for the Moon and asteroids. Our simulating show, in particular, that parameter b lies in range 0.002 - 0.03 for majority of the asteroids. In researching the asteroid spectrum oddities this circumstance should bear in mind.

References: [1] Hapke B. (2001) *JGR*, *106*, 10039-10073. [2] Lucey P.G., et.al.(1998) *JGR*, *103*, 3679-3699. [3] Starukhina L.V. and Shkuratov Yu.G. (2001) *Icarus*, *152*, 275-281. [4] Murchie S., et.al. (2001) *LPSC XXXII*, Abstr.#1614. [5] Shestopalov D.I. (2002) About Optical Maturation of Eros Regolith (submitted in *Proc. ACM Conference, Berlin*). [6] Golubeva L.F., et.al.(1980) *Sov Astron.J*, *57*, 1047-1055. [7] Lupishko D.F. and Mohamed R.A. (1996) *Icarus*, *119*, 209-213. [8] Shestopalov D.I., et.al. (1989) *Kinemat. and Phys. Cel. Bodies, 5*, 25-31. [9] Shkuratov Yu.G. et.al. (1999) *Icarus*, *137*, 222-234. [10] Chapman C.R., and Gaffey M.J. (1979) *in Asteroids* (T.Gehrels, ed.) Tucson, Arizona: Univ. of Arizona Press. [11] Zellner B., et al. (1985) *Icarus*, *61*, 355-416. [12] Binzel R.P., et.al. (1995) *Icarus*, *115*, 1-35. [13] Gaffey M.J. (1976) *JGR*, *81*, 905-920. [14] Johnson P.V. and Christy R.W. (1974) *Phys. Rev.B, 9,* 5056-5070. [15] Shkuratov Yu., et.al (1999) *Icarus*, *137*, 235-246.